

Assessing Colorado's Geothermal Potential to Generate Electricity

COLORADO GEOLOGICAL SURVEY



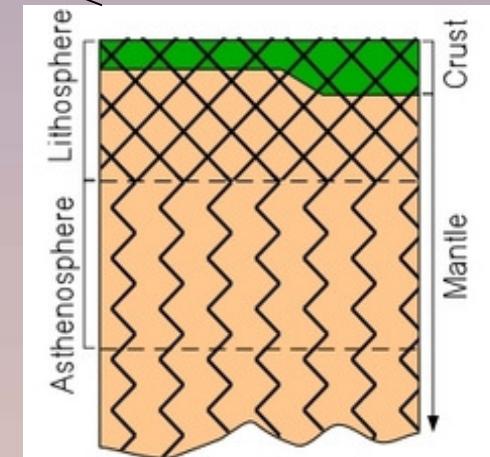
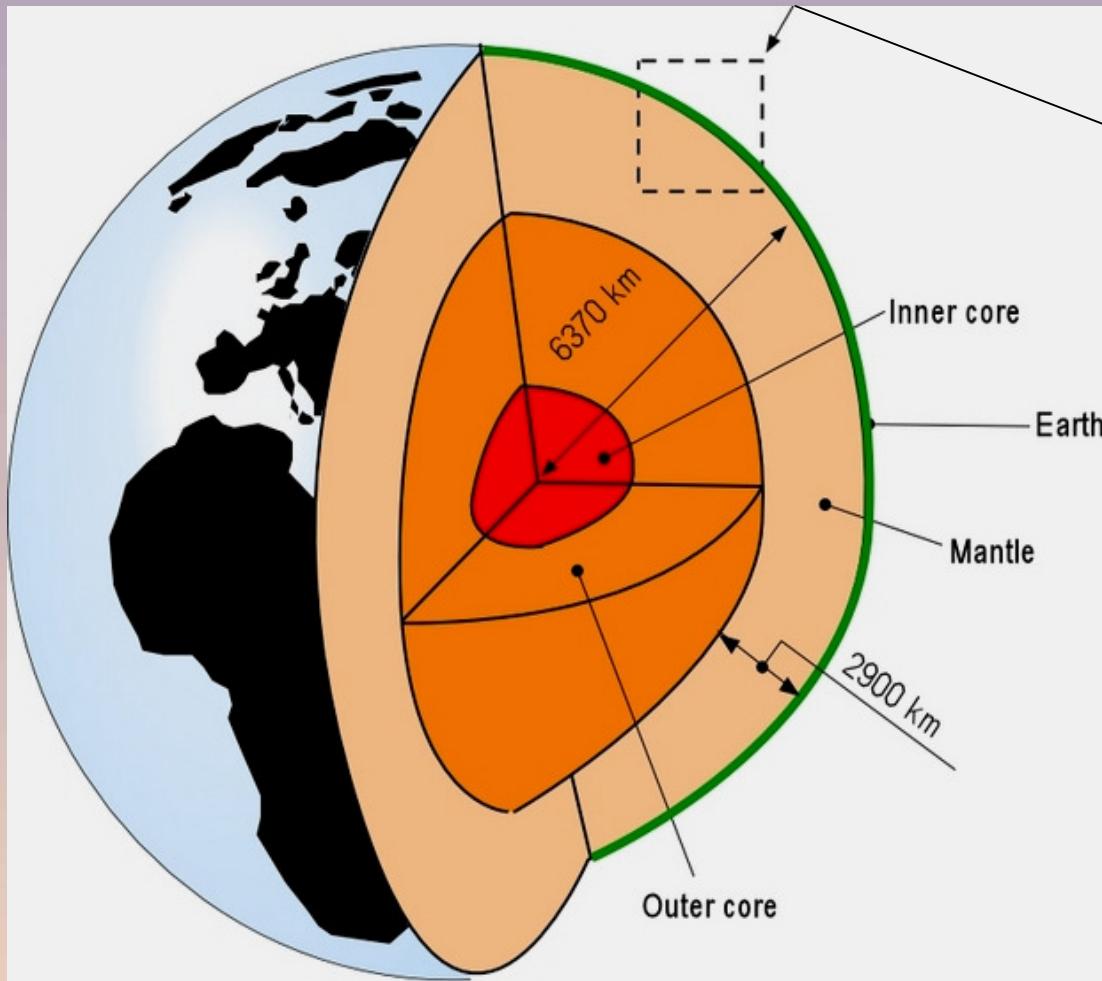
Presentation Outline:

- Background and Geology
- Current Uses in Colorado
- Indicators of Geothermal Potential
- New Data, Mapping, and Studies

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Geology of Geothermal Resources

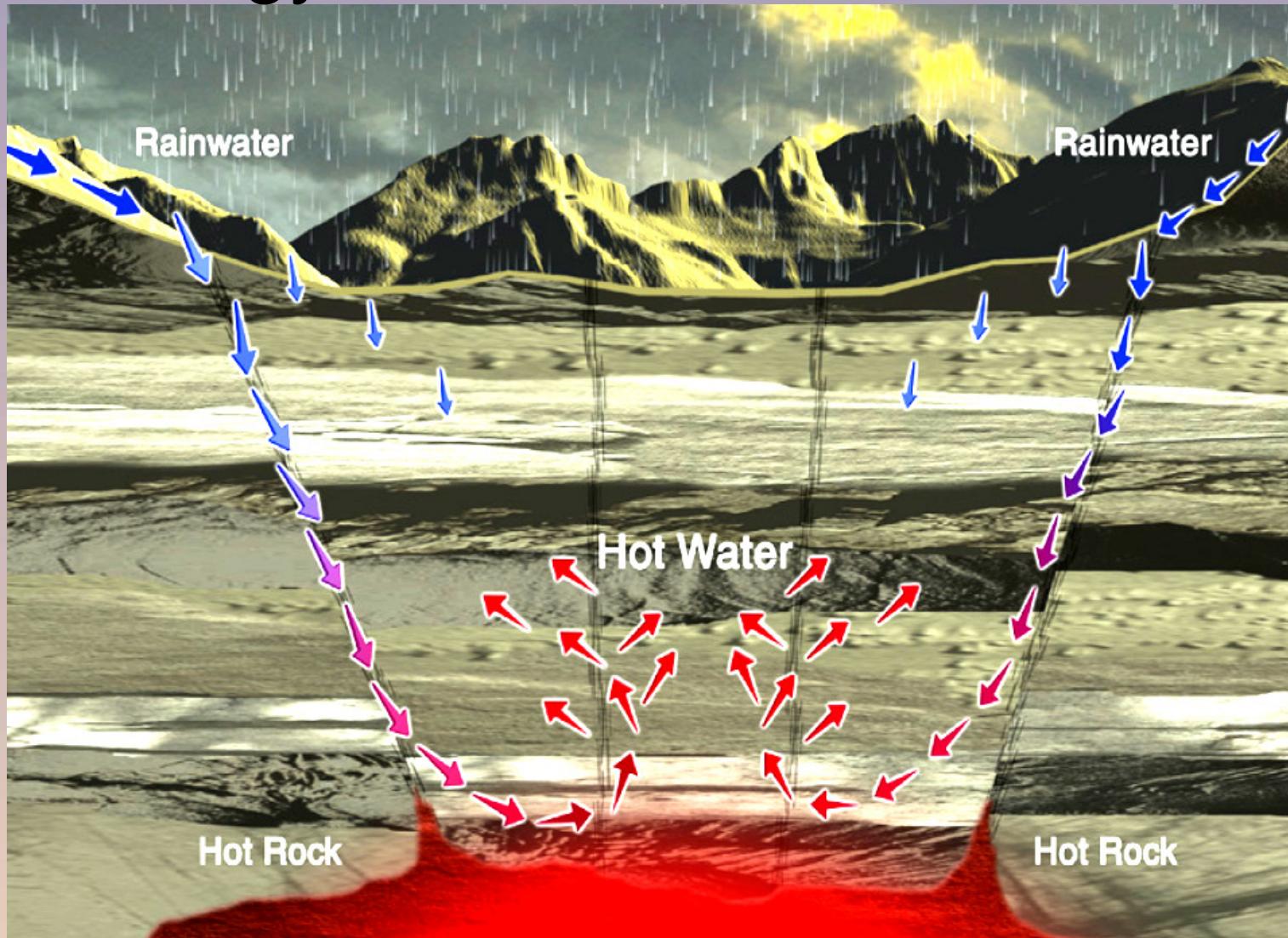


from Dickson and Fanelli, 2004

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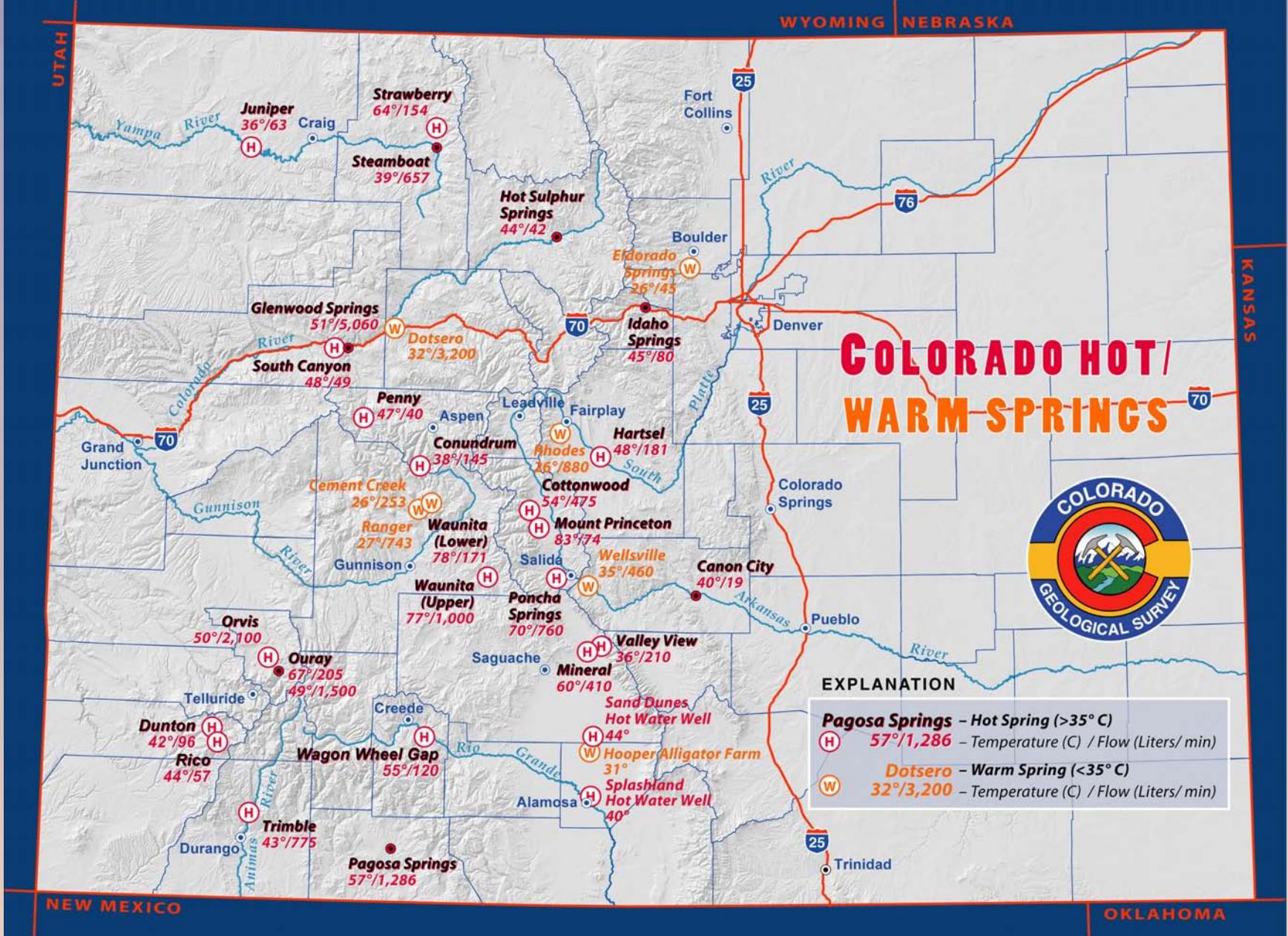
Geology of Geothermal Resources



Courtesy Geothermal Education Association

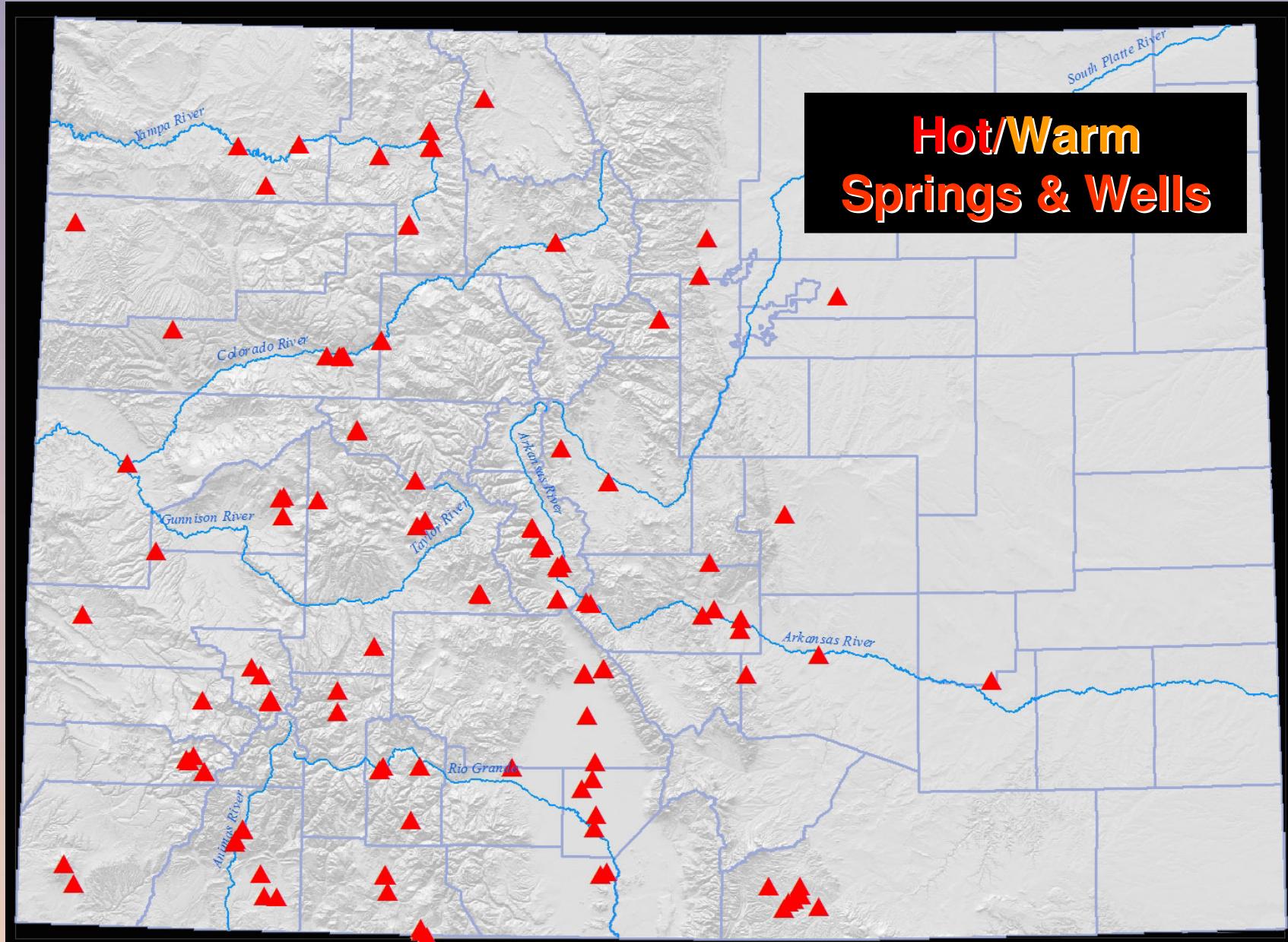


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Cottonwood Hot Springs, Buena Vista



Yampah Hot Spring, Glenwood Springs



Wuanita Hot Spring, Gunnison Valley



Rico Hot Spring

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Alligator Farm, Hooper well, San Luis Basin

- Spas & Pools - 18 sites
- Space Heating - 15 sites
- Aquaculture - 4 sites
- District Heating - 1 site
- Greenhouses - 1 site

...What's Missing???

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Electrical Power Generation!



Binary Geothermal Plant Heber, CA

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Criteria for geothermal power potential:

- Quaternary volcanism ➤ 5 Quaternary volcanoes
- Quaternary faulting ➤ >90 Quaternary faults
- High heat flow ➤ 2nd largest heat flow anomaly in US >100 mW/m²

Colorado is also outstanding in these criteria!

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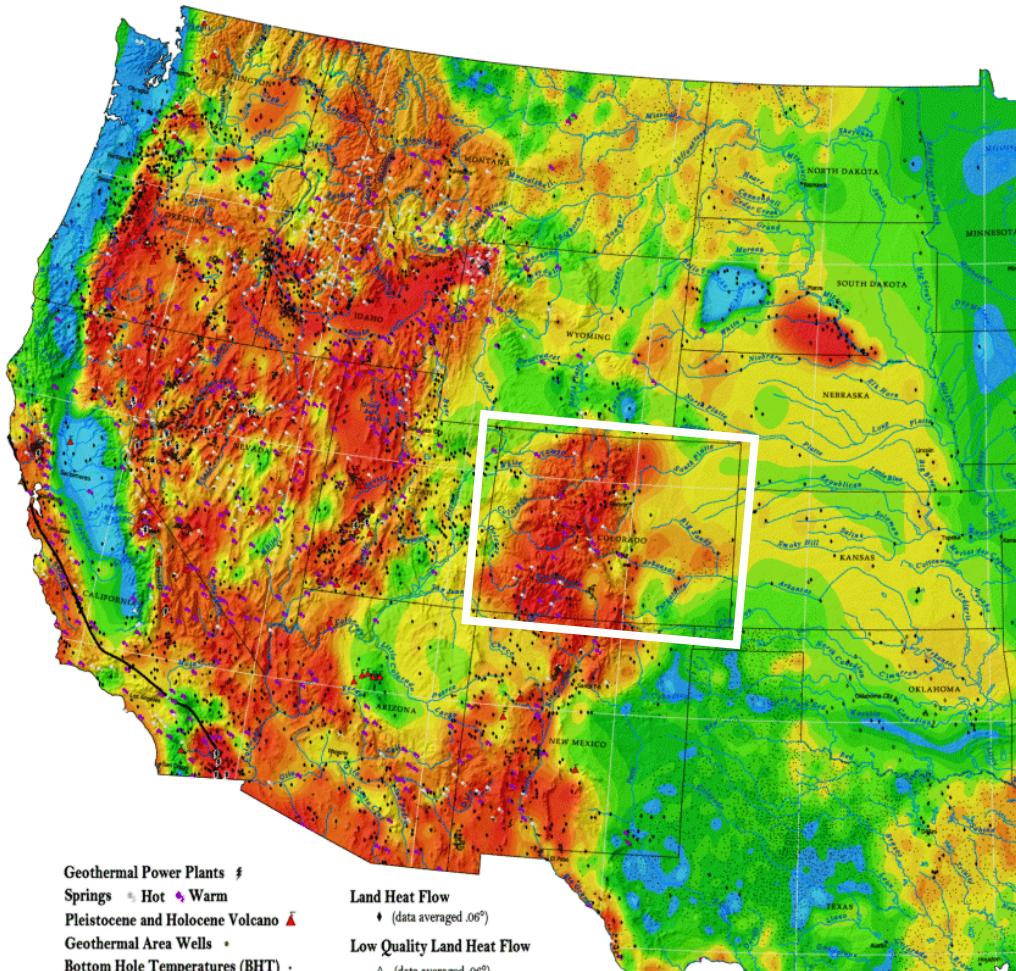
Heat Flow

Causes of high heat flow:

- 1) Thinner crustal rock
- 2) Igneous pluton at depth
- 3) Resident heat
- 4) Upwelling of deep, heated groundwater
- 5) Concentration of radioactive elements

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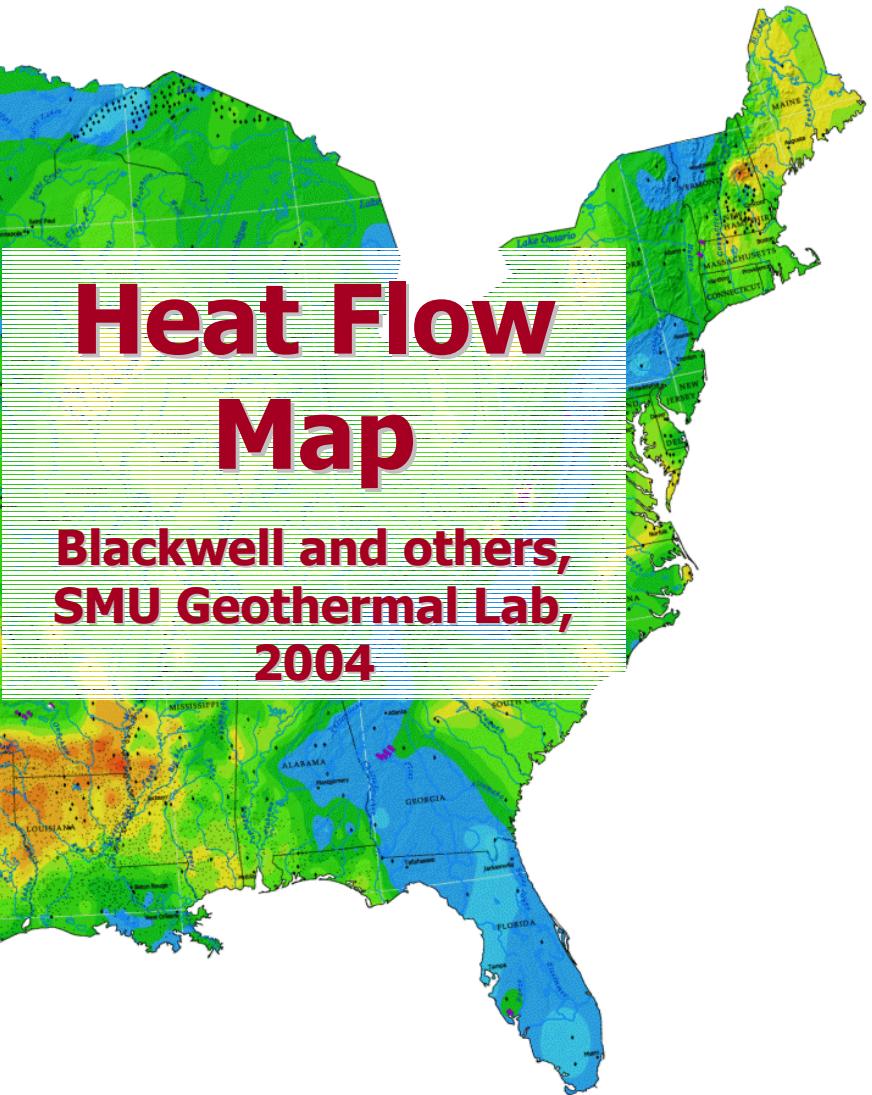




SMU Geothermal Lab, Geothermal Map of United States, 2004

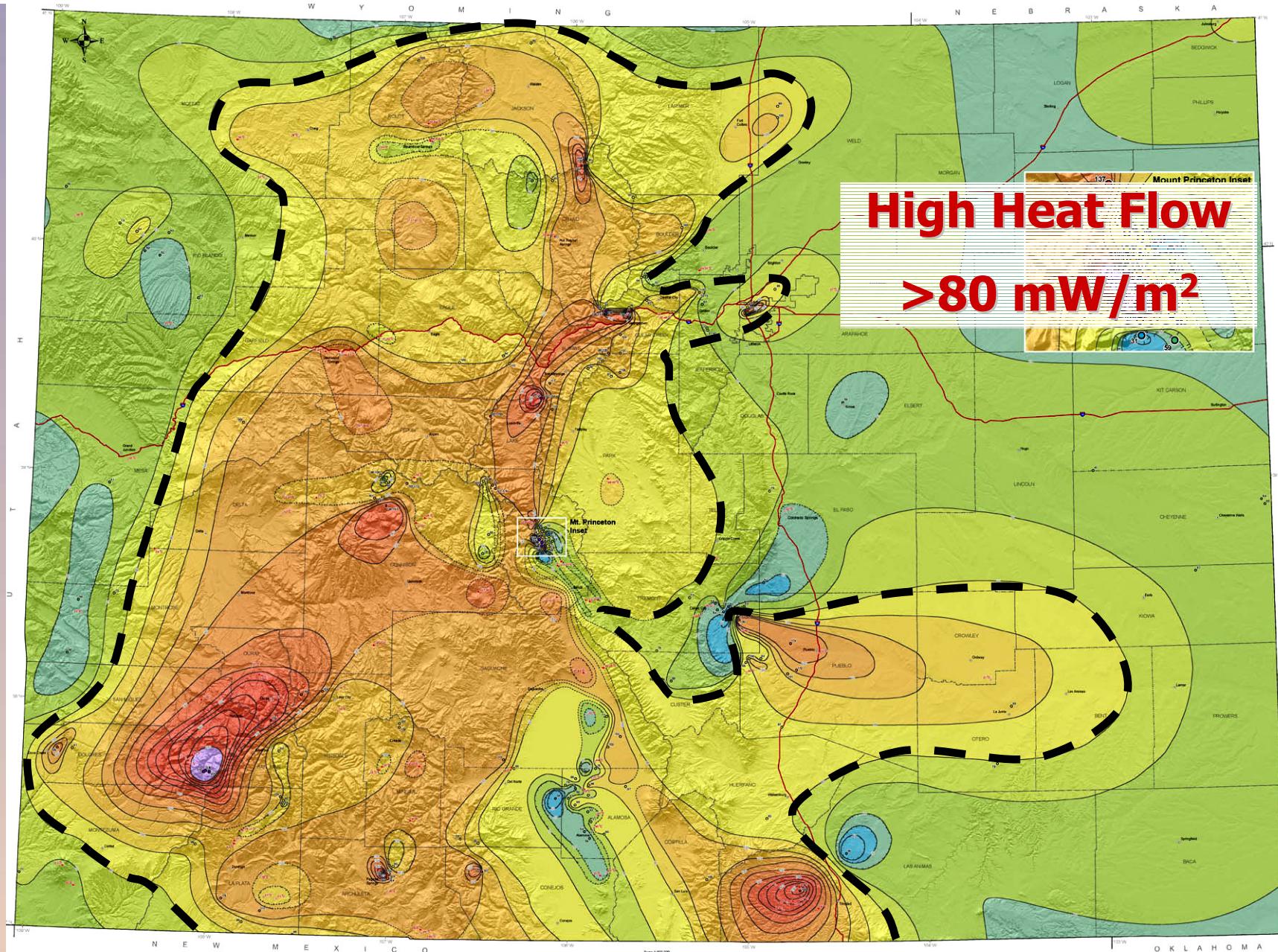
Heat Flow Map

**Blackwell and others,
SMU Geothermal Lab,
2004**



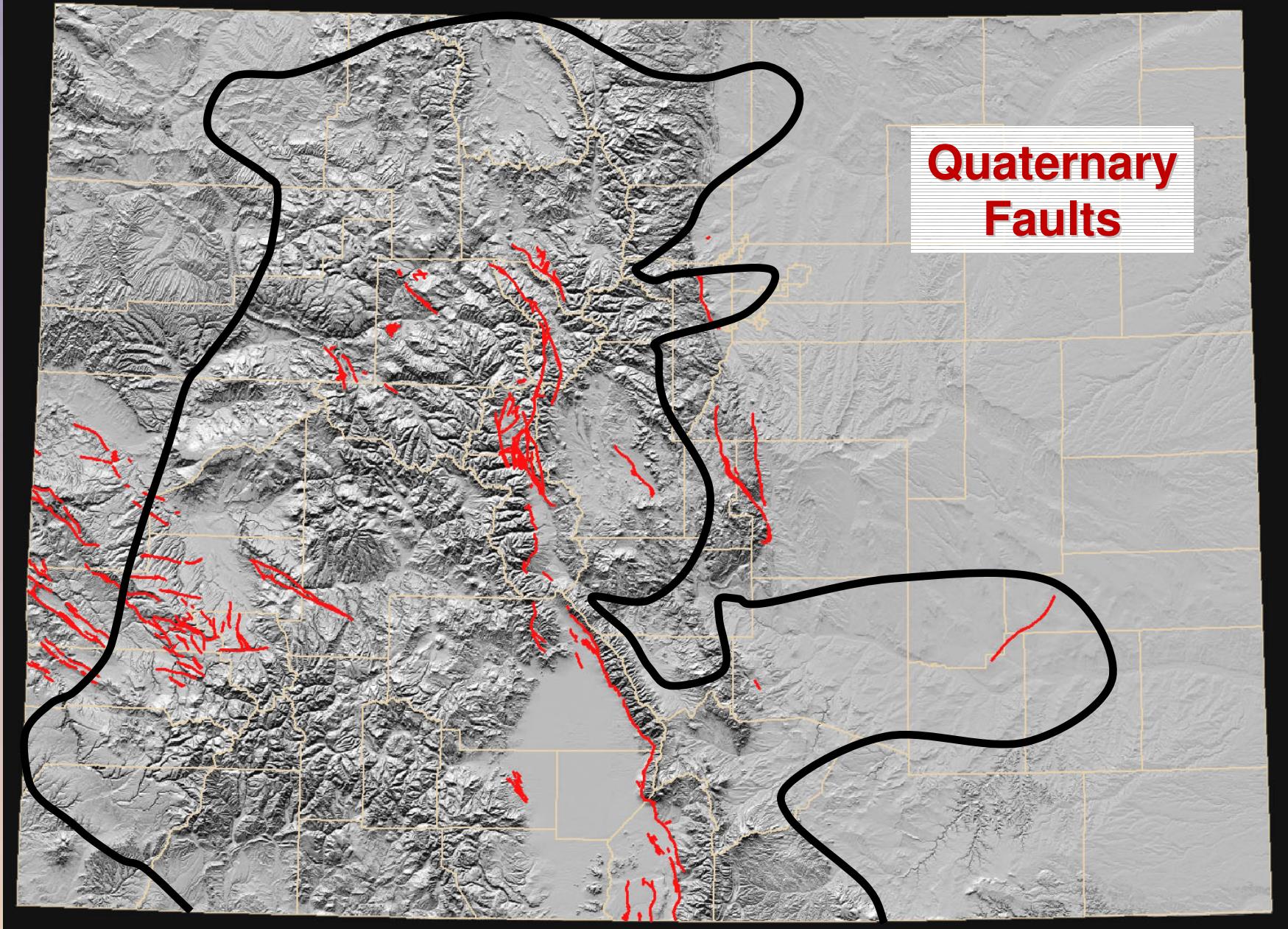
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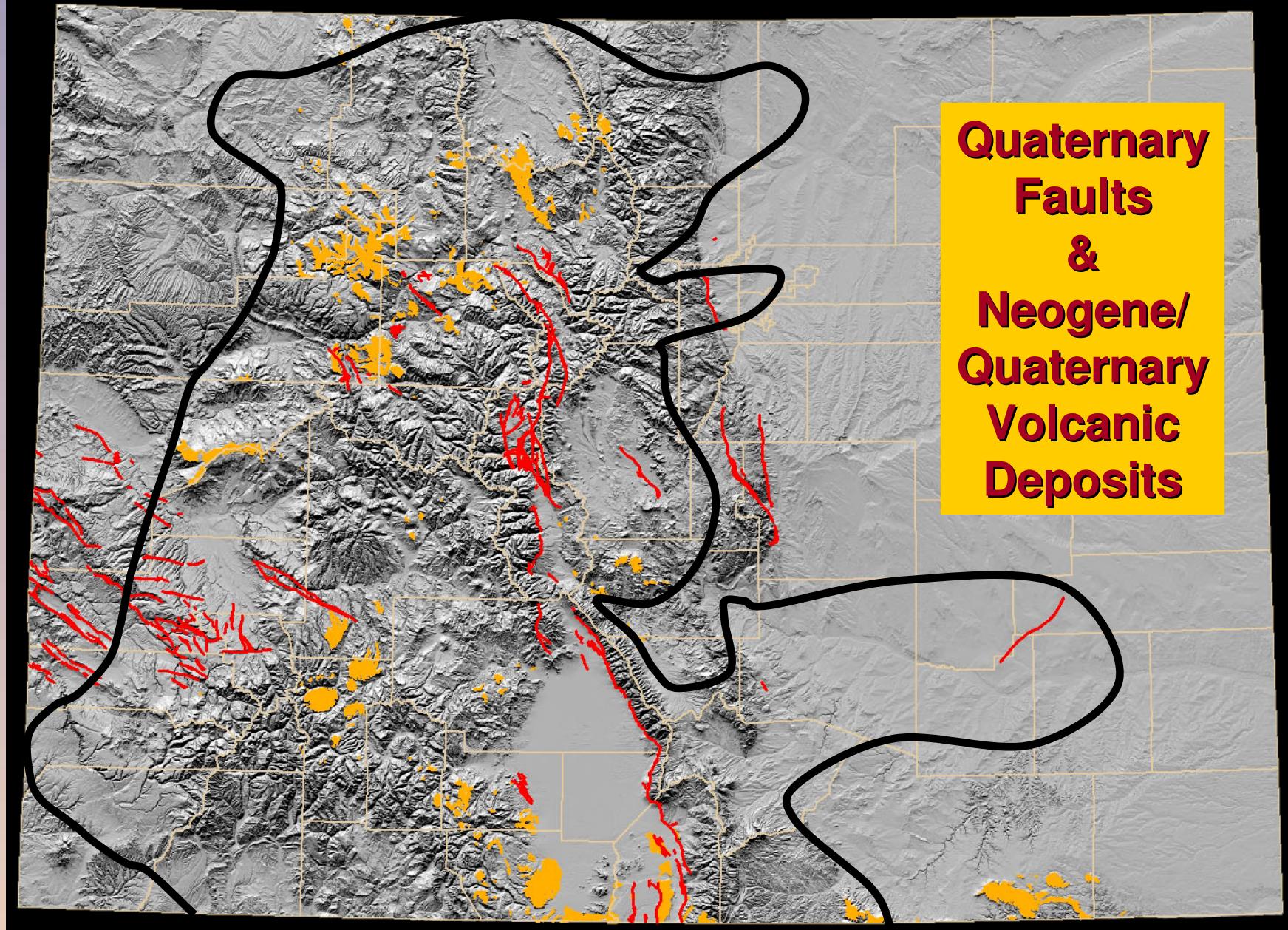




Machette, 2003, USGS OFR 03-417

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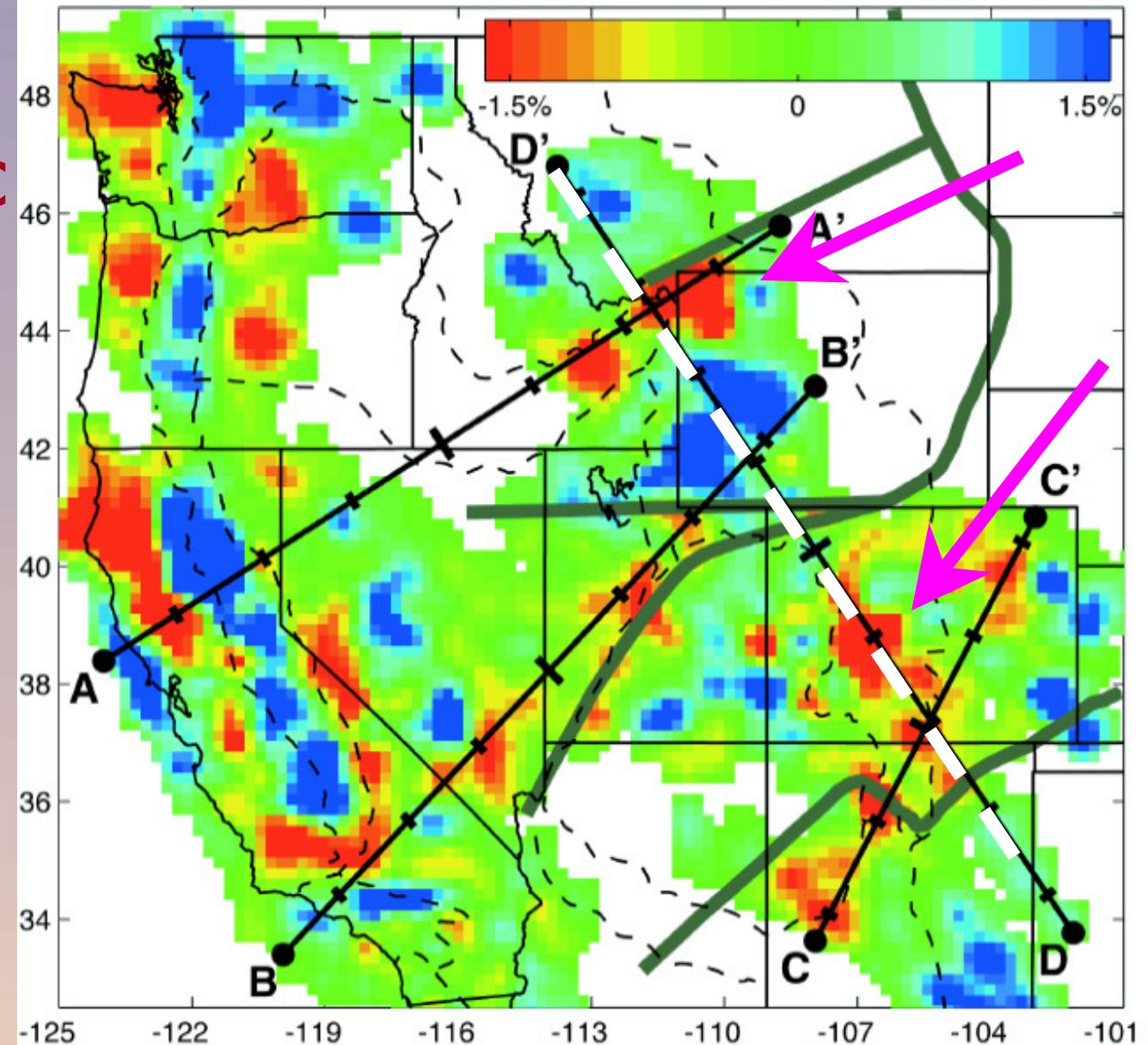
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Tomographic P-wave velocity variations

Map at 100 Km Depth

Yellow/red = Low
Velocity Material



from Dueker, Yuan, & Zurek, 2001

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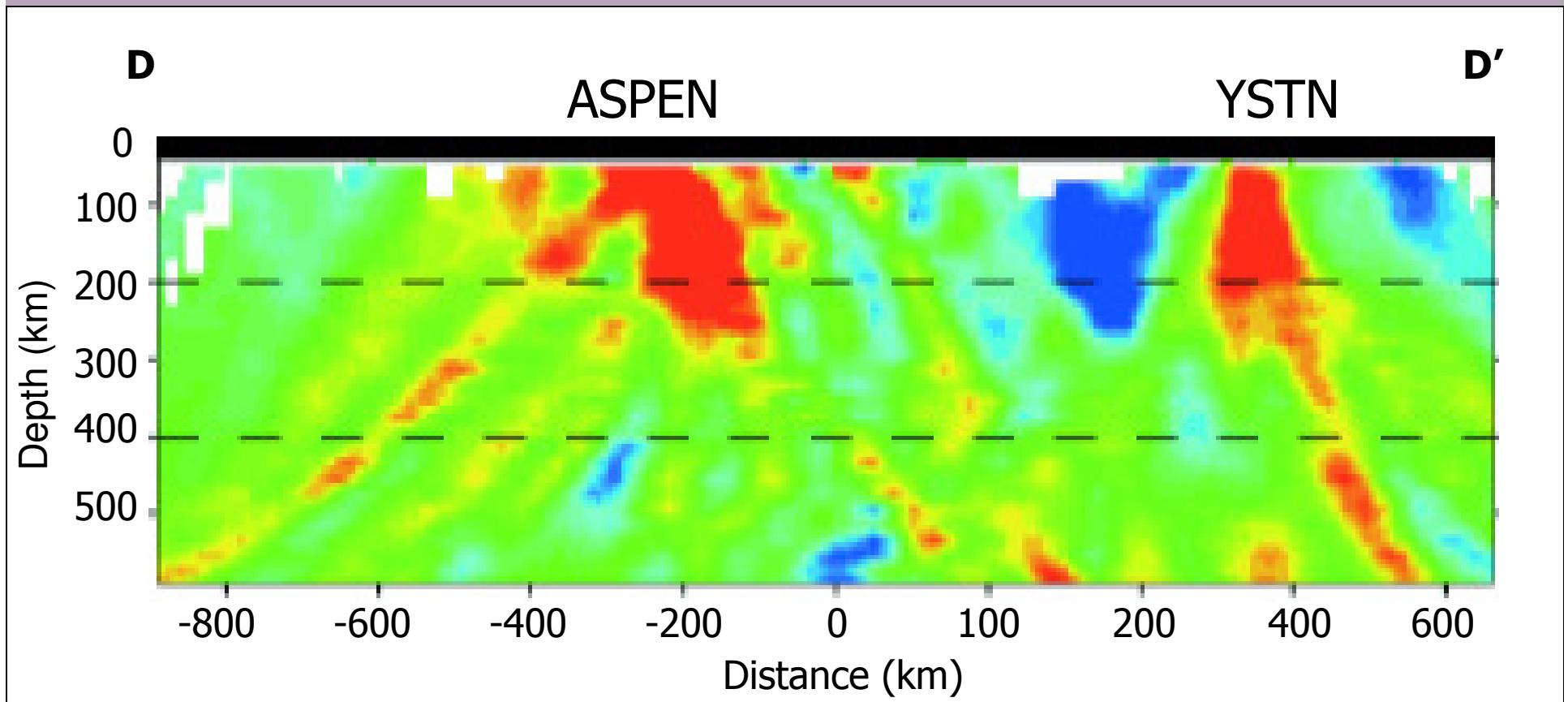


Tomographic P-wave velocity variations

Cross-Section View

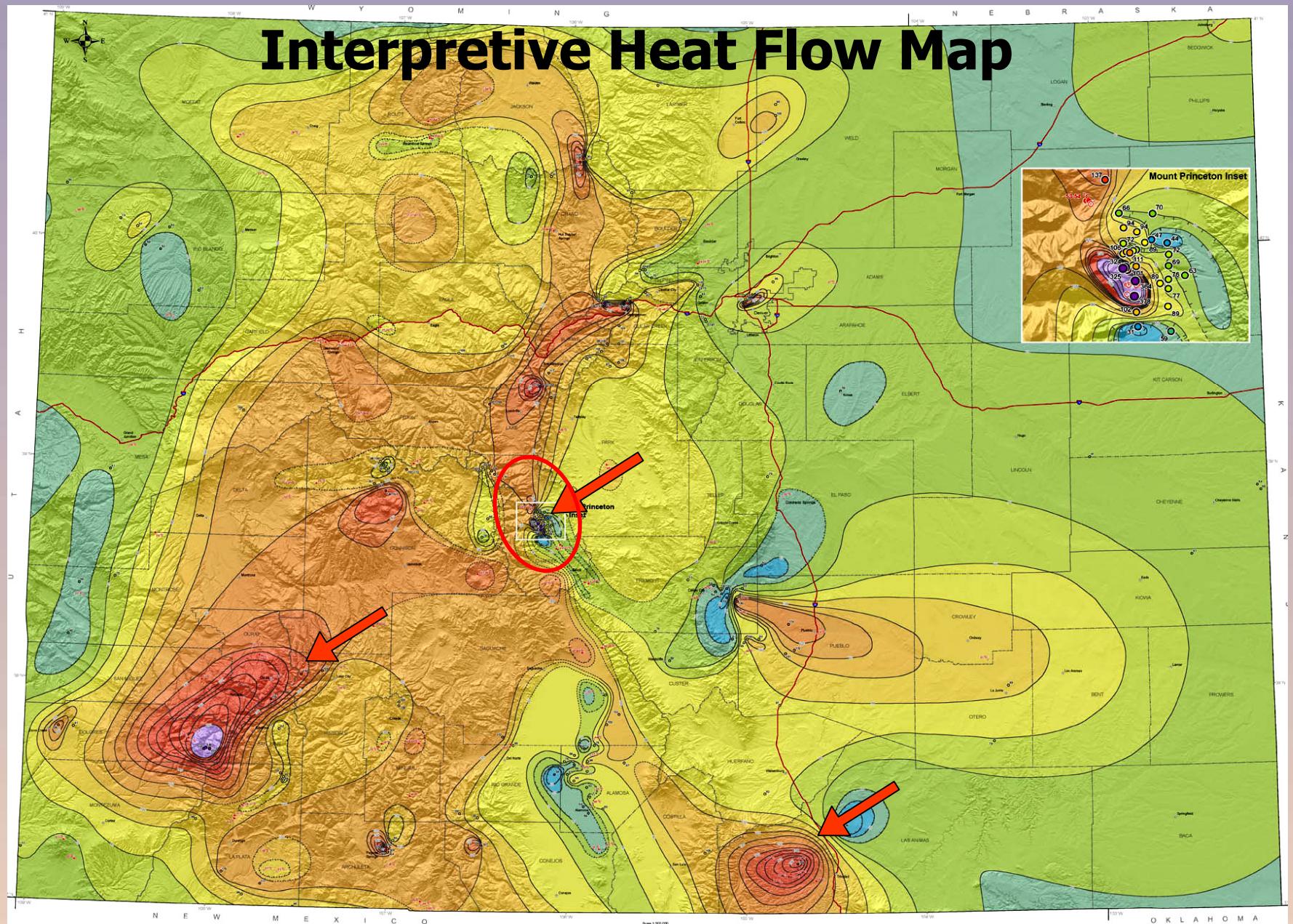
South

North



from Dueker, Yuan, & Zurek, 2001

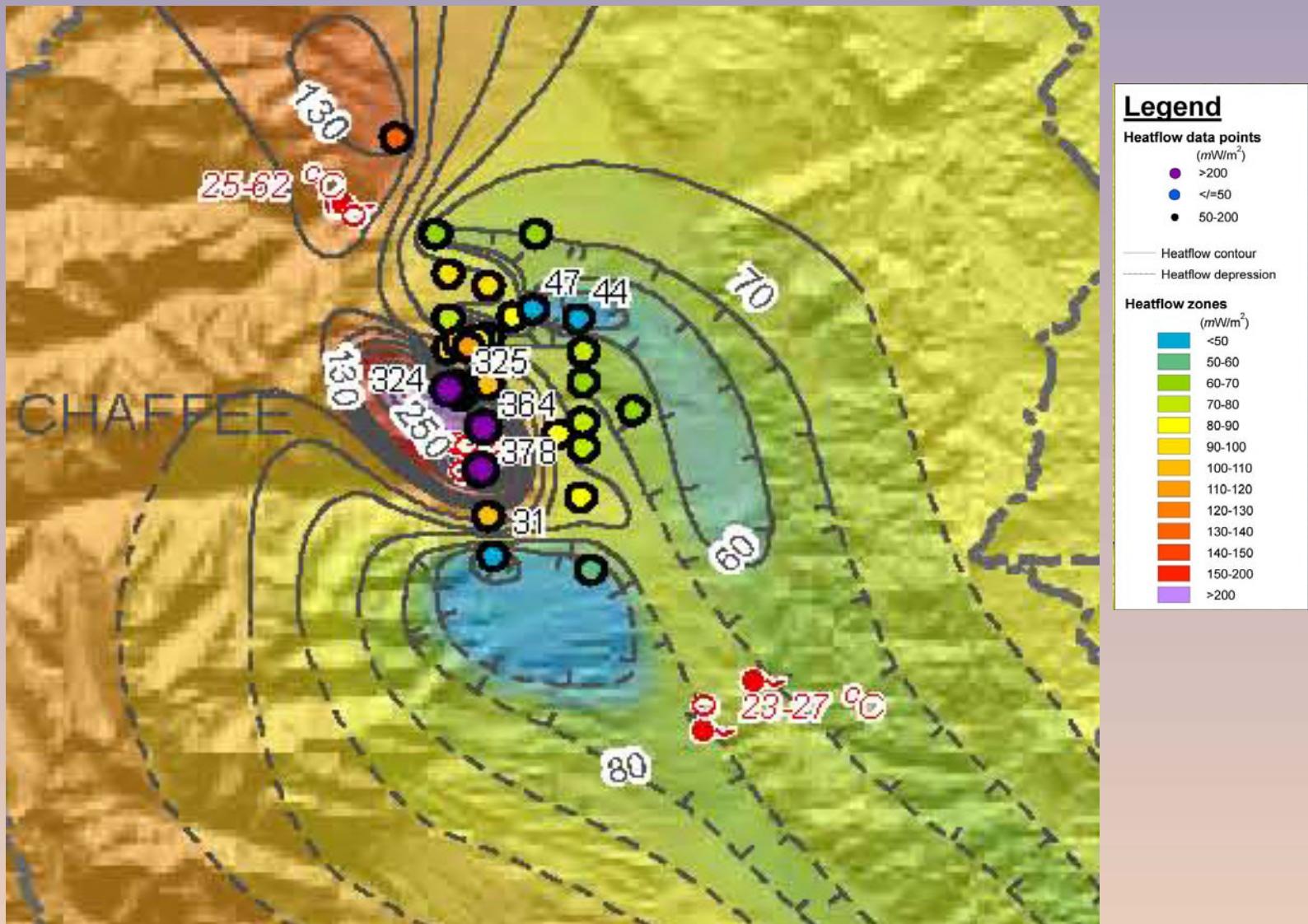




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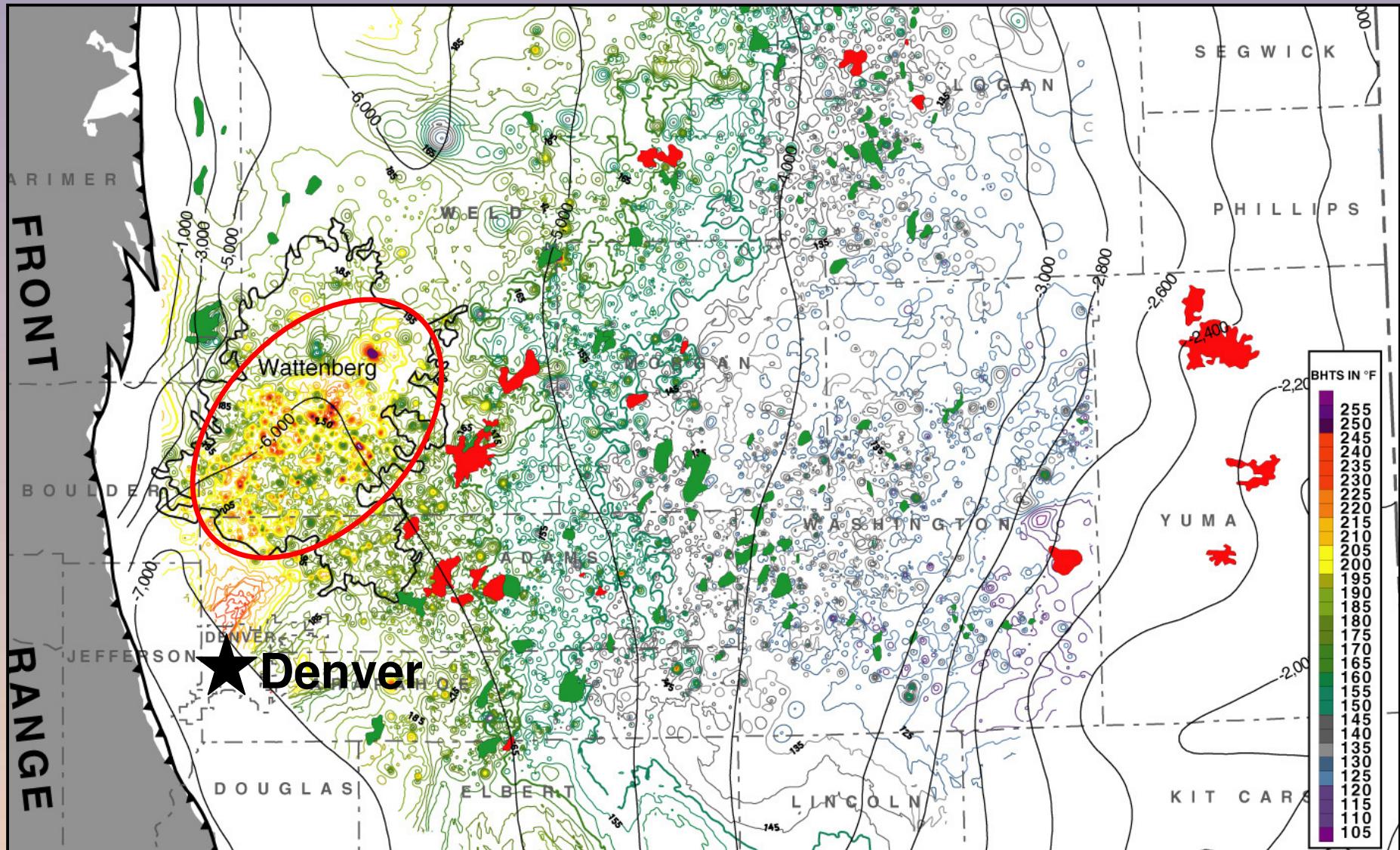
Heat Flow Map – Mt. Princeton



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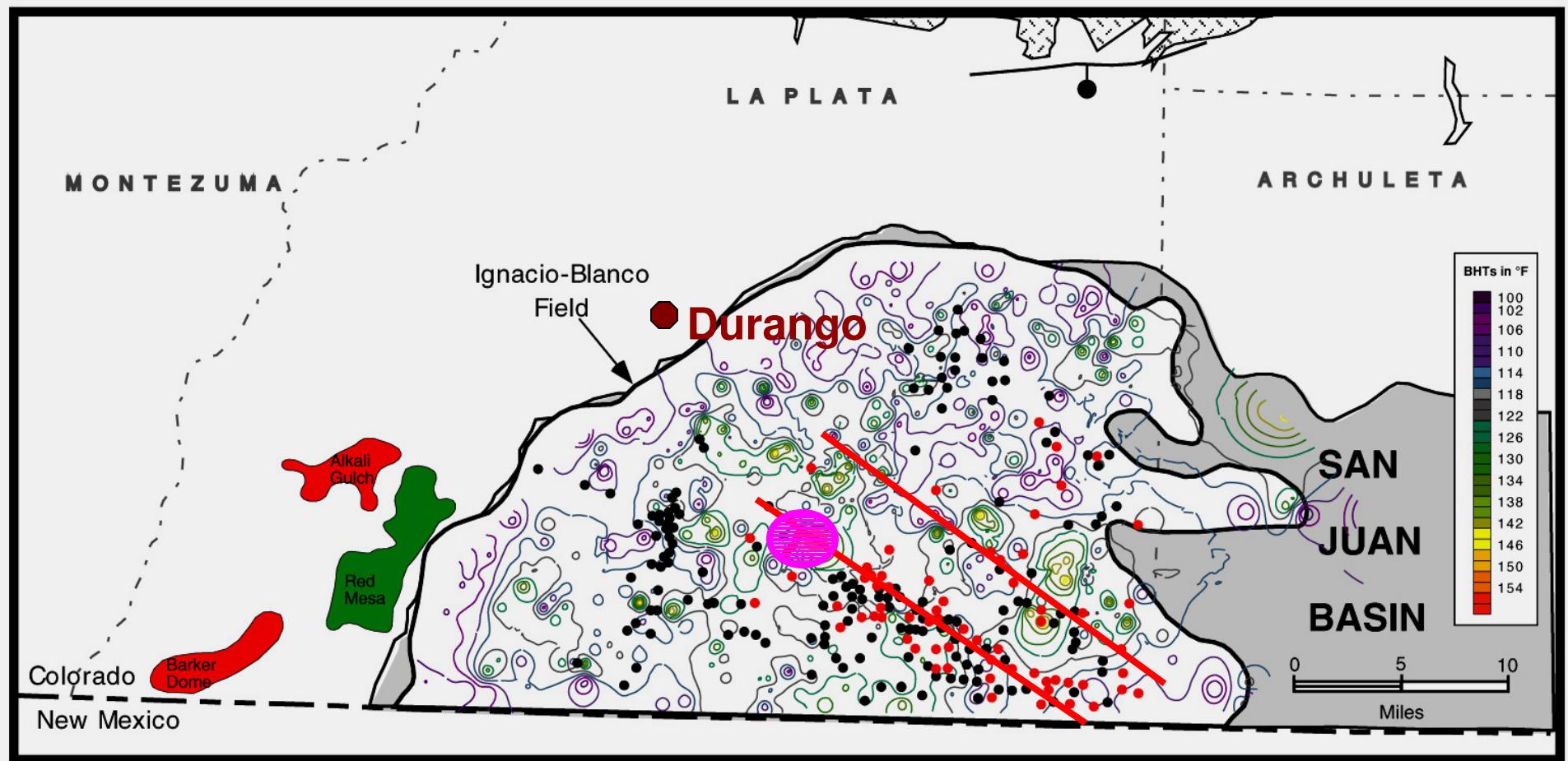
Bottom Hole Temps – Denver Basin



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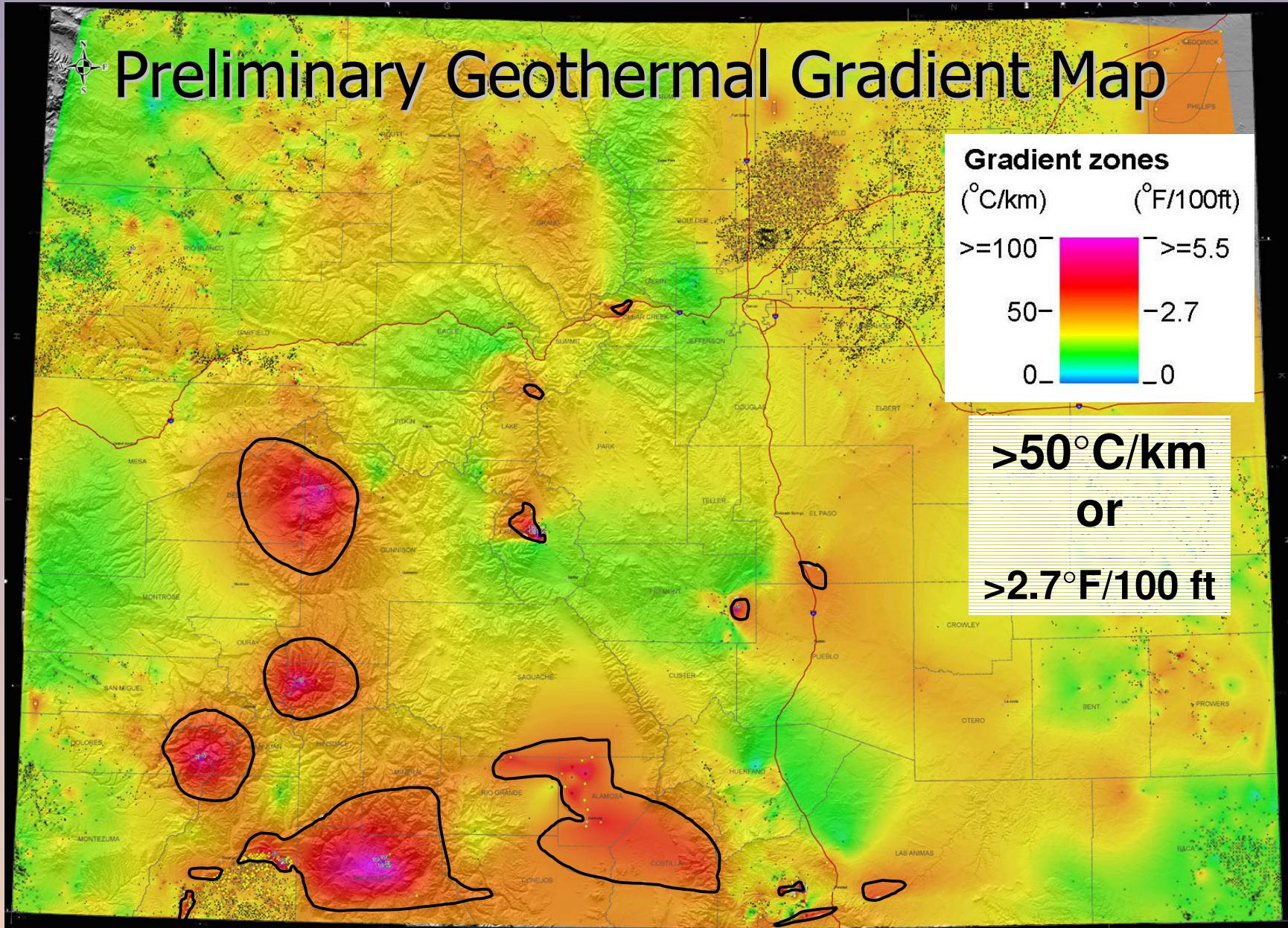


Bottom Hole Temps – San Juan Basin



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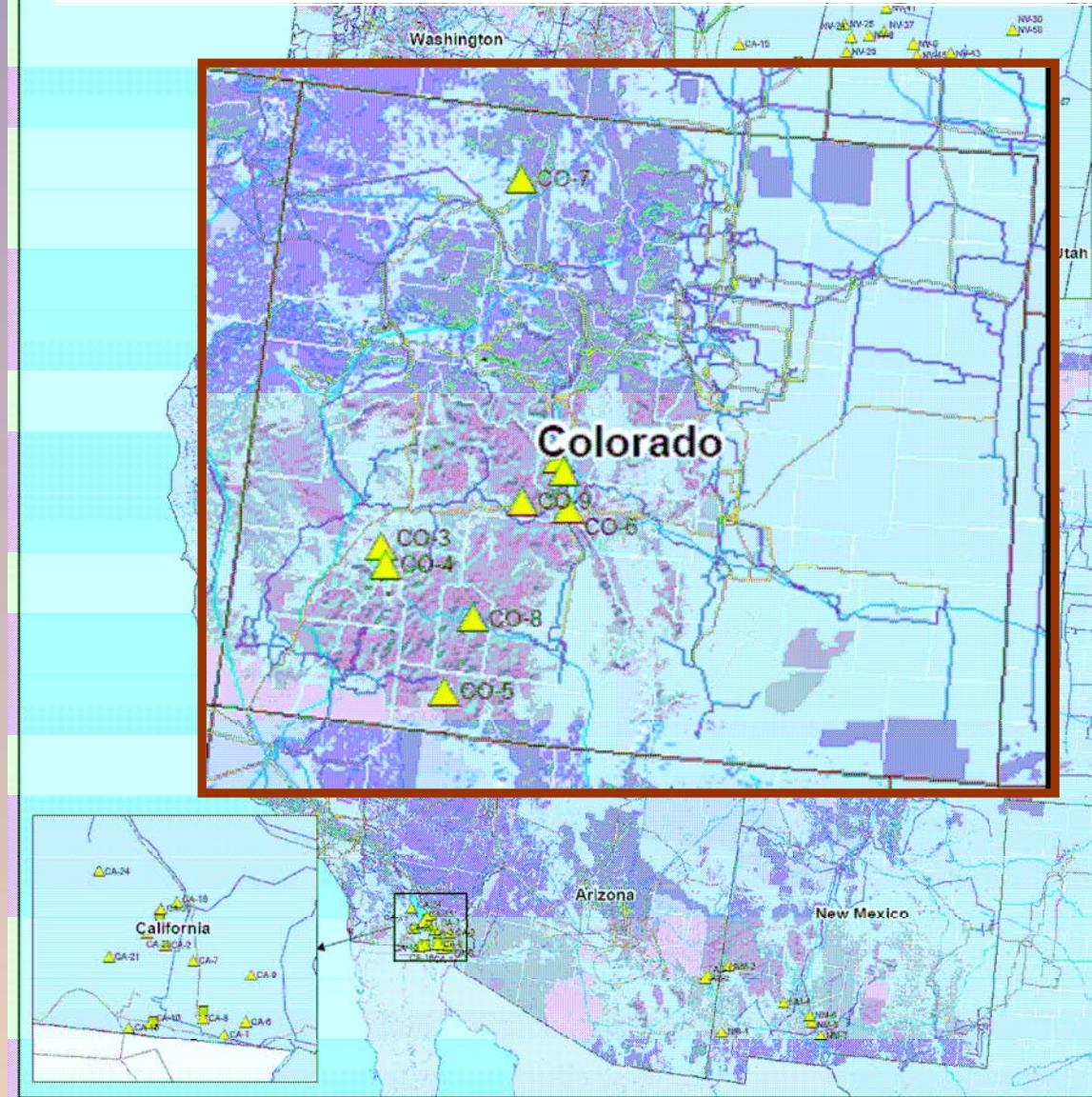




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Geothermal Power Potential Western U.S.



Legend:

CA-1 Calistoga Hot Springs
CA-2 Clear Lake Volcanic Field Area
CA-3 Coso Area
CA-4 Domes
CA-5 East Valley
CA-6 East Valley
CA-7 Goshen
CA-8 Heber

NV-11 NV-12 NV-13 NV-14 NV-15 NV-16 NV-17 NV-18 NV-19 NV-20 NV-21 NV-22 NV-23 NV-24 NV-25 NV-26 NV-27 NV-28 NV-29 NV-30 NV-31 NV-32 NV-33 NV-34 NV-35 NV-36 NV-37 NV-38 NV-39 NV-40 NV-41 NV-42 NV-43 NV-44 NV-45 NV-46 NV-47 NV-48 NV-49 NV-50

CO-1 Cottonwood Hot Springs
CO-2 Mt. Princeton Hot Springs
CO-3 Orvis Hot Springs
CO-4 Ouray
CO-5 Pagosa Springs
CO-6 Poncha Hot Springs
CO-7 Routt Hot Springs
CO-8 Wagon Wheel Gap
CO-9 Waunita Hot Springs

NM-1 Loser San Francisco Hot Springs
NM-2 Midway Hot Springs
NM-3 Rachel's Hot Springs
NM-4 San Diego
NM-5 Adens Valley
NM-6 Arco
NM-7 Aztec
NM-8 Bataan Hot Springs
NM-9 Bullion Mountain
NM-10 Cimarron Hot Springs
NM-11 Rio Grande Valley
NM-12 Black Rock Desert
NM-13 Elko
NM-14 Eureka
NM-15 Brady Hot Springs
NM-16 Calico
NM-17 Crescent Valley
NM-18 Desert Peak Area
NM-19 Elko
NM-20 Gold Butte
NM-21 Dry Lakes
NM-22 Dyke Hot Springs
NM-23 Eureka Valley
NM-24 Gold Butte
NM-25 Decker
NM-26 Fallon/Canyon Lake
NM-27 Fallon-Suds Wells
NM-28 Gold Butte
NM-29 Fish Lake
NM-30 Fish Lake Valley - Emigrant Peak
NM-31 Fly Ranch (Granite Ranch)
NM-32 Gold Butte
NM-33 Great Boiling Spring (Decker)
NM-34 Hawthorne
NM-35 Hazel (Black Butte)
NM-36 Hot Creek
NM-37 Hot Sulphur Springs
NM-38 Hot Sulphur Springs (Tuscarora)
NM-39 Hyder Hot Springs
NM-40 Indian Creek
NM-41 Indian Creek - Black Granite Mtn)
NM-42 Lead Hot Springs
NM-43 Lee & Allen Hot Springs
NM-44 Lockett
NM-45 Lovelock
NM-46 Mountain
NM-47 Mojave Mountains
NM-48 New York Canyon
NM-49 North Fork - Black Winter Peak
NM-50 Pinto Hot Springs
NM-51 Provoce Mountain
NM-52 Purple Mountain Valley
NM-53 Rhyolite Indian Reserve
NM-54 Rose Creek
NM-55 Ryer Patch (Humoldt House District)
NM-56 Salt Wells
NM-57 Shoshone Desert Area (Empire)
NM-58 Shoshone River
NM-59 Silver Peak
NM-60 Shoshone Creek Valley Area
NM-61 Soda Lake Area
NM-62 Soda Hot Springs
NM-63 Southern Pacific
NM-64 Tule Springs
NM-65 Walker Valley
NM-66 Walker Valley
NM-67 Walker Valley
NM-68 Walker Valley
NM-69 Walker Valley
NM-70 Walker Valley

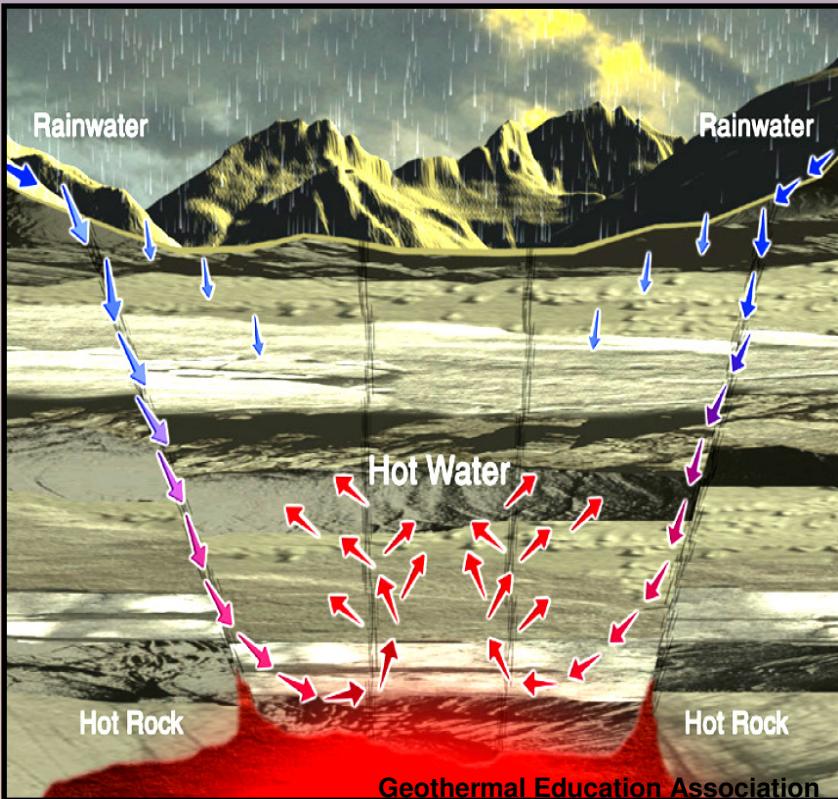
Laney
and
Brizzee,
2005, INL

<http://www.geo-energy.org/information/resources.asp>



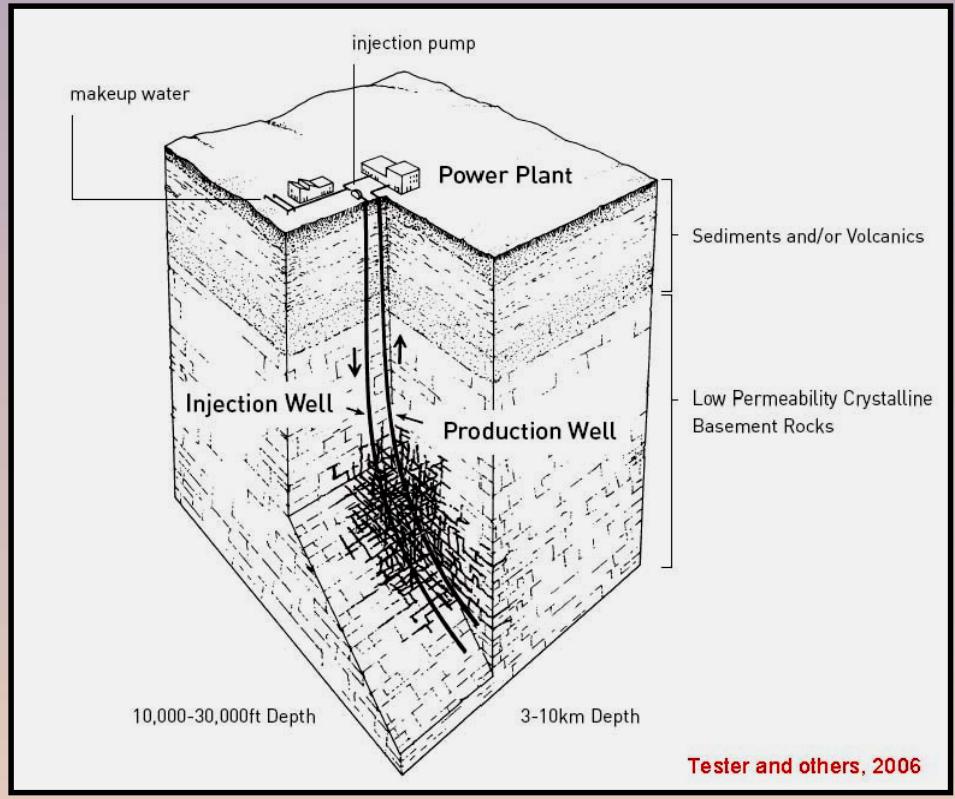
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Hydrothermal Systems



<10,000 ft (<3 km)

Enhanced Geothermal Systems



10,000-30,000 ft (3-10 km)

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MIT Study - Enhanced Geothermal Systems

3.5 6.5
**For EGS, Colorado has the
one of the best
high temp resources in the
US.**

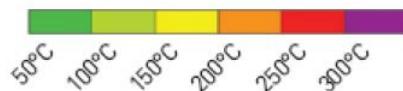


Figure 1.5 Temperatures at a depth of 10 km.

from Tester and
others, 2006



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MIT Study - Enhanced Geothermal Systems

Table 2.2. High-grade EGS areas
(>200°C at depths of about 4 km)

Table 2.2. High-grade EGS areas (>200°C at depths of about 4 km).	
Region	Characteristics
Great Basin	30% of the 500 km x 500 km area is at temperatures > 200°C. Highly variable geologic and thermal conditions with some drilling confirming deep conditions. Large-scale fluid flow both laterally and horizontally so extensive fracturing at depth in many areas. The stress regime is extensional. Rocks are highly variable with depths of 4-10 km, mostly sedimentary with some granite and other basement rock types.

2-24

Southern Rocky Mountains

25% of the 100 km x 300 km area is at temperatures > 200°C. Geology is variable. Area includes the northern Rio Grande Rift and the Valles Caldera. Can have sediments over basement, generally thermal conditions in basement are unknown. Both high crustal radioactivity and high mantle heat flow contribute to surface heat flow. **Probably highest basement EGS potential on a large scale.**

metamorphosed sedimentary rocks at depth. There is extensive drilling in the existing geothermal systems and limited background data available from hydrocarbon exploration.

Clear Lake Volcanic Field 50% of the 30 x 30 km area is at temperatures > 200°C (steam reservoir is 5 km x 10 km). Low-permeability Franciscan sediments, may find granite at deeper depths. Possible access problems. Significant deep drilling with temperatures of 200°C at 2 km over a large area.

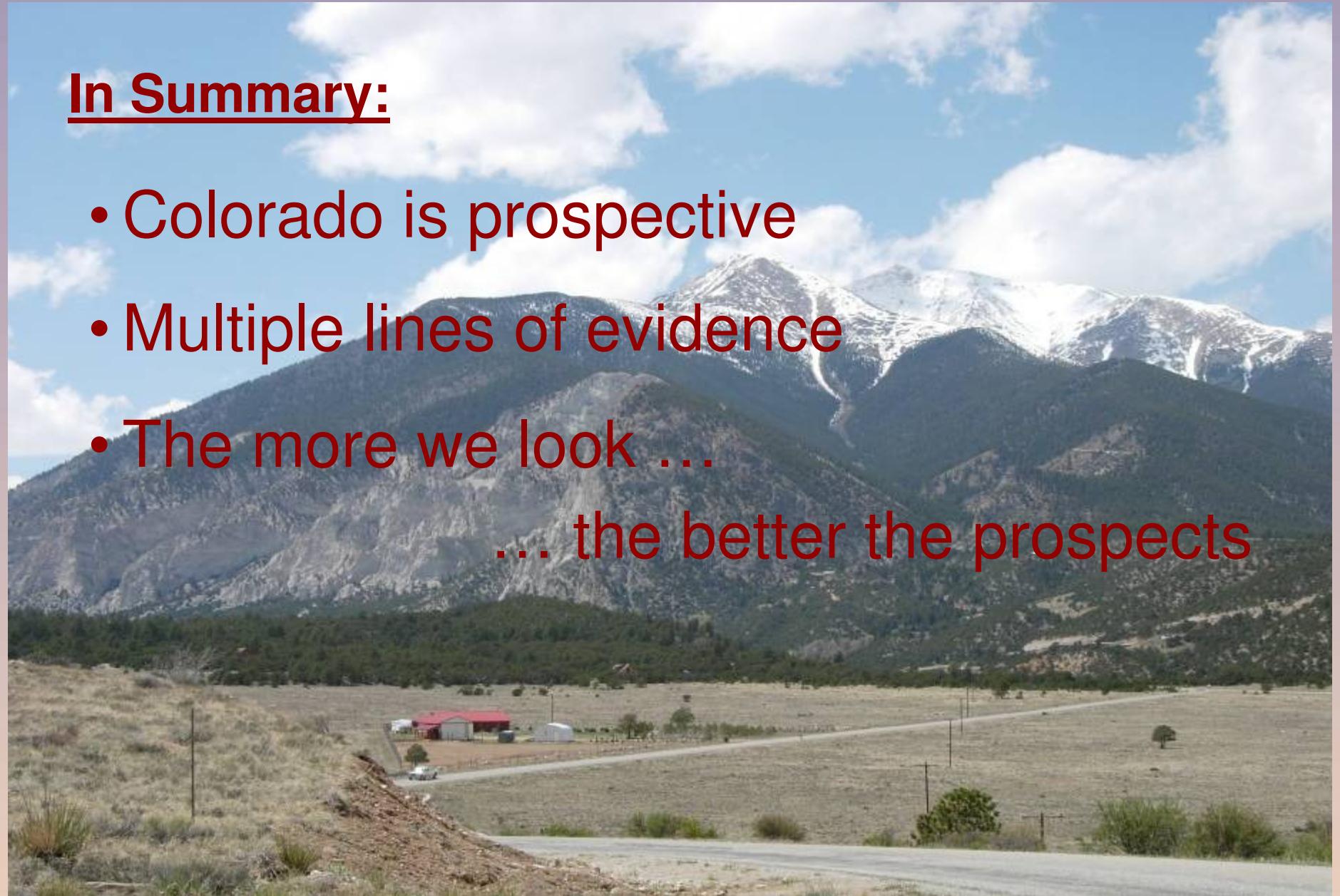
from Tester and others, 2006



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In Summary:

- Colorado is prospective
- Multiple lines of evidence
- The more we look ...
... the better the prospects



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**Thank you
and
Enjoy Colorado!**



Mt. Princeton, Chaffee County

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